CHEM 2110 **TEST 3** **28 APRIL, 2012**

Chemistry for Medicine

Name: MODEL ANSWERS **ID Number:** ____________

Time: 1½ hours

Useful constants: $N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$1\ \text{amu} = 1.6605 \times 10^{-24}\ \text{g}$

$1\ \text{atm} = 760\ \text{torr} = 760\ \text{mmHg} = 1.01325 \times 10^{5}\ \text{Pa}$

$R = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}$

$K_a\ (NH_4^+) = 5.6 \times 10^{-10}$

1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226	89 **Ac†** (227)															

QUESTION	SCORE	MAXIMUM MARKS
1		
2		
TOTAL		

QUESTION 1

(a) Assign oxidation states to all atoms in each of the following substances:

$(NH_4)_2Fe(SO_4)_2$ Fe = +2 ; H = +1 ; O = −2 ; N = −3, S = +6

Zinc iodite Zn = +2; I = +3 ; O = −2

AlH_4^- Al = +3 ; H = −1

$Na_2S_4O_6$ Na = +1 ; O = −2 ; S = +5/2

CsO_2 Cs = +1 ; O = −1/2

(b) What type of electrolyte is each of the following?

0.500 *M* hydrocyanic acid weak electrolyte

0.500 *M* sodium chloride solution strong electrolyte

0.500 *M* sugar solution nonelectrolyte

0.500 *M* hydrobromic acid strong electrolyte

0.500 *M* hypochlorous acid weak electrolyte

(c) In the laboratory, what can you use to test the acidity of an aqueous solution?

a pH meter

a universal indicator paper

an acid-base indicator

litmus paper

(d) For each of the following solutions, write **pH > 7**, **pH < 7** or **pH = 7**

HCOOK pH > 7

Pure water at 25°C pH = 7

Lemon juice pH < 7

KNO_2 pH > 7

$FeCl_3 \cdot 6H_2O$ pH < 7

Blood pH > 7 (pH ~ 7.4)

(e) (i) What is a buffer solution prepared from?

The conjugate acid-base pair of a weak acid or weak base

(ii) What are the conditions for the most effective buffer system?

$[HA] = [A^-] \Rightarrow pH = pK_a$

High concentration of HA and A^-

(iii) Name and derive the "buffer equation".

The Henderson-Hasselbalch equation

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = [H_3O^+] \times \frac{[A^-]}{[HA]}$$

$$-\log K_a = -\log[H_3O^+] - \log\frac{[A^-]}{[HA]}$$

$$pK_a = pH - \log\frac{[A^-]}{[HA]}$$

$$\therefore pH = pK_a + \log\frac{[A^-]}{[HA]}$$

(iv) Give your own example of a buffer system. (Only **one** example!)

(v) What is the buffer system in the blood?

(vi) Why should blood be buffered?

(f) For each of the following chemical processes, **name the type of reaction** occurring and give a **net ionic equation**. You can give **more than one name** for some of the reactions.

(i) Magnesium reacts with hydroiodic acid in aqueous solution

Net ionic equation: $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

Name(s):

Redox reaction

(ii) Barium hydroxide reacts with phosphoric acid in aqueous solution

Net ionic equation:

$3Ba^{2+}(aq) + 6OH^-(aq) + 2H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6H_2O(l)$

Name(s):

Acid-base reaction; neutralisation; precipitation rxn

(iii) Sodium hydrogen carbonate reacts with acetic acid to produce carbon dioxide, water and a salt in aqueous solution

Net ionic equation:

$HCO_3^-(aq) + CH_3COOH(aq) \rightarrow CO_2(aq) + H_2O(l) + CH_3COO^-(aq)$

Name(s):

acid-base reaction

(iv) A potassium sulfide solution is added to an aqueous solution containing cadmium ions

Net ionic equation:

$S^{2-}(aq) + Cd^{2+}(aq) \rightarrow CdS(s)$

Name(s):

precipitation reaction

QUESTION 2

(a) (i) Convert 750 torr to kPa. What method should you use? Dimensional Analysis

$$750 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} \times \frac{1.01325 \times 10^5 \text{ Pa}}{1 \text{ atm}} \times \frac{\text{kPa}}{10^3 \text{ Pa}}$$

$$= 1.0 \times 10^2 \text{ kPa}$$

(ii) Determine the molarity of 28% *w/w* $NH_3(aq)$ (d = 0.90 g/cm^3).

$$\frac{28}{100} \times \frac{0.90 \text{ g}}{\text{cm}^3} \times \frac{\text{cm}^3}{\text{mL}} \times \frac{\text{mL}}{10^{-3} \text{ L}} \times \frac{1 \text{ mol}}{17.03(4) \text{ g}} = 15 \text{ mol/L}$$

(iii) If this solution in part (ii) above is diluted 1000 times, what is the pH of the final solution?

$$\text{Dilute } NH_3(aq) = \frac{15 \text{ mol/L}}{10^3} = 0.015 \text{ mol/L}$$

	$NH_3(aq)$ + $H_2O(l)$ $\rightleftharpoons$	$NH_4^+(aq)$ +	$OH^-(aq)$
Init.	0.015 mol/L	0	0
Equil.	$0.015 - x$	x	x

$$K_b = \frac{x^2}{0.015 - x} \cong \frac{x^2}{0.015} = 1.8 \times 10^{-5} \quad \therefore x = 5.2 \times 10^{-4} \text{ mol/L } OH^-$$

$$pOH = 3.28 \quad \therefore pH = 14.00 - 3.28 = 10.72$$

(b) $MnO_4^-(aq)$ reacts with oxalic acid ($H_2C_2O_4$) to produce manganese(II) ions and carbon dioxide.

A 0.450-g sample of oxalic acid is dissolved in distilled water to form 50.00 mL of solution.

Then 40.00 mL of this solution of oxalic acid is added to 24.00 mL of 0.0500 *M* $MnO_4^-(aq)$.

The gas produced is collected in a flask where it exerts a pressure of 224.5 torr at 27°C.

Determine the size of the flask.

$$M_{H_2C_2O_4} = 2(1.008) + 2(12.01) + 4(16.00) = 90.03(6)\ g/mol$$

$$n_{H_2C_2O_4} = \frac{0.450\,g}{90.03(6)\ g/mol} = 5.00 \times 10^{-3}\ mol$$

$$C_{H_2C_2O_4} = \frac{n}{V} = \frac{5.00 \times 10^{-3}\ mol}{50.00 \times 10^{-3}\ L} = 0.100\ mol/L$$

$$2(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O)$$
$$5(H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-)$$

$$2MnO_4^-(aq) + 6H^+(aq) + 5H_2C_2O_4(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

$C = 0.0500\ mol/L$ | $C = 0.100\ mol/L$

$V = 24.00 \times 10^{-3} L$ | $V = 40.00 \times 10^{-3} L$

$n = CV = 1.20 \times 10^{-3}\ mol$ | $n = CV = 4.00 \times 10^{-3}\ mol$

$$\frac{MnO_4^-}{2\ mol} \qquad \frac{H_2C_2O_4}{5\ mol}$$
$$1.20 \times 10^{-3}\ mol \qquad x_{REQ} \qquad \therefore x_{REQ} = 3.00 \times 10^{-3}\ mol$$

$\therefore$ $H_2C_2O_4$ is present in excess amount.

MnO_4^- is the limiting reactant

$$\frac{MnO_4^-}{2\ mol} \qquad \frac{CO_2}{10\ mol}$$
$$1.20 \times 10^{-3}\ mol \qquad x_{produced}$$

$$\therefore x_{CO_2} = 6.00 \times 10^{-3}\ mol$$

$$T = 27 + 273.15 = 300.\ K$$

$$P = 224.5\ torr / 760\ torr/atm = 0.2954\ atm$$

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$= \frac{6.00 \times 10^{-3}\ mol \times 0.08206\ L\,atm\,K^{-1}\,mol^{-1} \times 300.\ K}{0.2954\ atm}$$

$$= 0.500\ L$$

or 500. mL

(c) A molecule of an unknown **triprotic acid** contains **6 carbon atoms** and **7 oxygen atoms**.
It also contains **other atoms of hydrogen that are not acidic**.
This acid is **4.197% by mass of hydrogen**.

2.3055 g of the triprotic acid is dissolved in water to form 100.00 mL of solution **(Solution A)**

Then **25.00 mL of Solution A** is diluted to **100.00 mL of Solution B**.

15.00 mL of Solution B [redacted] reacts completely with **30.00 mL of 0.0450 *M* NaOH(aq)**

Determine the molecular formula of the unknown triprotic acid.

$H_3A(aq) + 3NaOH(aq) \rightarrow Na_3A(aq) + 3H_2O(\ell)$

$V = 15.00 \times 10^{-3} L$ $\quad$ $C = 0.0450\ mol/L$

$V = 30.00 \times 10^{-3} L$

$n = CV = 1.35 \times 10^{-3} mol$

$\therefore n_{H_3A}$ reacted $= \frac{1}{3} \times 1.35 \times 10^{-3} mol = 4.50 \times 10^{-4} mol$

$C_{H_3A} = \frac{n}{V} = \frac{4.50 \times 10^{-4} mol}{15.00 \times 10^{-3} L} = 0.0300\ mol/L$ in Solution B

C_{H_3A} in Solution A:

$C_A V_A = C_B V_B$

$C_A \times 25.00 \times 10^{-3} L = 0.0300\ mol/L \times 100.00 \times 10^{-3} L$

$\therefore C_A = 0.120\ mol/L$

$\therefore n_{H_3A}$ in 100.00 mL of solution $= CV$

$= 0.120\ mol/L \times 100.00 \times 10^{-3} L$

$= 0.0120\ mol$

$\therefore M_{H_3A} = \frac{m}{n} = \frac{2.3055\ g}{0.0120\ mol} = 192\ g/mol$

$\% H = 4.197\% = \frac{1.008\,n}{192} \times 100\%$ $\quad \therefore n = 7.99 \sim 8$

$\therefore$ 8 H atoms
3 acidic H atoms

$\therefore$ Molecular formula is $H_3C_6H_5O_7$ (citric acid)